DECLASSIFIED [redacted]

UNCLASSIFIED [redacted]

AEDC-TR-65-57

ARO, INC.
DOCUMENT CONTROL
NO 1G-601-343
COPY 1X OF 38
SERIES A PAGES 46

AEDC-OI 75-40

(cy 1 e)

(U) AERODYNAMIC PERFORMANCE OF VARIOUS HYPERFLO AND HEMISFLO PARACHUTES AT MACH NUMBERS FROM 1.8 TO 3.0

FEB 17 1975

APR 09 1975
APPROVED FOR RELEASE
OFFICE OF INFORMATION
ARNOLD ENGINEERING DEVELOPMENT CENTER
ARNOLD AIR FORCE STATION, TENN. 37389

David E. A. Reichenau

ARO, Inc.

Classified by ______
Subject To General Declassification
Schedule Of Executive Order 11652
Automatically Downgraded At Two
Year Intervals.
Declassified On December 31, 1972

This document has been approved for public release
its distribution is unlimited. Per TAB 74-26, Dtd 20 Dec, 74

March 1965

PROPULSION WIND TUNNEL FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE

[redacted]

DECLASSIFIED [redacted]

UNCLASSIFIED

NOTICES

DECLASSIFIED

[redacted] UNCLASSIFIED

AEDC-TR-65-57

(U) AERODYNAMIC PERFORMANCE OF VARIOUS HYPERFLO AND HEMISFLO PARACHUTES AT MACH NUMBERS FROM 1.8 TO 3.0

Classified By ____________
Subject To General Declassification
Schedule Of Executive Order 11652
Automatically Downgraded At Two
Year Intervals.
Declassified On December 31, 1972

David E. A. Reichenau

ARO, Inc.

This document has been approved for public release; its distribution is unlimited. PER TAB 74-26, dtd 20 Dec., 74

DECLASSIFIED [redacted] UNCLASSIFIED

FOREWORD

(U) The work reported herein was done at the request of the Research and Technology Division (RTD), Air Force Systems Command (AFSC), for the Air Force Flight Dynamics Laboratory (AFFDL), Wright-Patterson Air Force Base, Ohio under Program Element 62405364/6065.

(U) The results of the test presented were obtained by ARO, Inc. (a subsidiary of Sverdrup and Parcel, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), AFSC, Arnold Air Force Station, Tennessee, under Contract AF40(600)-1000. The test was conducted from December 13 to December 22, 1964 under ARO Project Number PS0508, and the report was submitted by the author on February 18, 1965.

(U) The dimensions and construction details of hyperflo parachutes are classified confidential. All data are unclassified, including motion pictures and still photographs of hyperflo parachutes which do not show construction or dimensional details.

(U) This report contains no classified information extracted from other classified documents.

(U) This technical report has been reviewed and is approved.

Francis M. Williams Major, USAF AF Representative, PWT DCS/Test	Jean A. Jack Colonel, USAF DCS/Test

UNCLASSIFIED ABSTRACT

(U) As an extension of studies previously completed, a test was conducted in the Propulsion Wind Tunnel, Supersonic (16S), to determine the effect of Mach number on the drag, stability, and inflation characteristics of a number of parachutes. The parachute characteristics were investigated at Mach numbers from 1.8 to 3.0 at pressure altitudes from 82,000 to 104,000 ft. Two general types of parachutes were tested: the hyperflo-type parachute using three general design concepts with porosities from 7.0 to 10.9 percent and the hemisflo-type parachute with and without reefing. Data obtained indicated that the hyperflo parachutes had good inflation characteristics at Mach number 2.6 and the drag decreased with increasing Mach number. The hemisflo parachutes had good inflation characteristics in the 1.8 to 2.2 Mach number range. For any given configuration, the stability was found to be essentially constant with varying Mach number.

CONTENTS

ILLUSTRATIONS

TABLES

NOMENCLATURE

C_DA	Parachute drag parameter, $\frac{\text{drag}}{q_\infty}$, ft^2
C_{D_o}	Parachute drag coefficient, $\frac{\text{drag}}{q_\infty S_o}$
D	Model centerbody diameter, 1.47 ft
D_o	Nominal diameter of parachute, ft
d_R	Reefed inlet diameter of parachute, ft
M_∞	Free-stream Mach number
q_∞	Free-stream dynamic pressure, psfa
S_o	Parachute surface area, ft^2
X	Distance from aft end of centerbody to parachute inlet, ft

SECTION I
INTRODUCTION

(U) A test was conducted in the Propulsion Wind Tunnel, Supersonic (16S), of the Propulsion Wind Tunnel Facility (PWT) at the Arnold Engineering Development Center (AEDC), AFSC, to determine the effect of Mach number on the drag, stability, and inflation characteristics of various parachute configurations. The parachutes investigated during this test were models of the hemisflo and hyperflo families of parachutes. An earlier phase of work with this same test objective was carried out at PWT in March 1964 (Ref. 1).

(U) The hemisflo and hyperflo parachute configurations were tested at Mach numbers from 1.8 to 3.0 at pressure altitudes from 82,000 to 104,000 ft. Various canopy porosities for the hyperflo parachutes were investigated in the Mach number range from 2.5 to 3.0. The 10-ft-diam hemisflo parachute characteristics were studied at reefed diameters of 2, 3, 4, and 5 ft, and the 6-ft-diam hemisflo parachute characteristics were studied with a shorter shroud line length. Drag data and motion pictures of the parachute configurations were taken during and after each deployment.

SECTION II
APPARATUS

2.1 TEST FACILITY

(U) Propulsion Wind Tunnel, Supersonic (16S) is a closed-circuit, continuous flow tunnel with a test section 16 ft in cross-section, capable of operating at supersonic Mach numbers from 1.65 to 3.2. The tunnel was designed for a stagnation pressure range from 100 to 2000 psfa and air temperatures up to 650°F. Tunnel humidity is controlled by removing tunnel air and supplying conditioned makeup air from an atmospheric dryer. A more complete description of the facility and its operating characteristics is contained in Ref. 2. The location and installation of the model centerbody in the tunnel are shown in Figs. 1 and 2.

2.2 TEST ARTICLE

2.2.1 Model Centerbody and Deployment System

(U) The parachutes tested during this investigation were deployed from a strut-mounted centerbody. Dimensions of the centerbody are presented in Fig. 3. The parachute riser line was attached to a strain-gage load cell by means of a swivel and cable arrangement. A shear pin, designed to protect the load cell, was used to connect the riser line to the swivel. The parachutes were packed into the aft end of the model centerbody (see Fig. 4) on a compressed spring. Once the holding pin was released by means of an explosive charge, the parachute pack was ejected from the centerbody into the airstream.

2.2.2 Parachutes

(U) The parachutes tested were of two general types: the hyperflo and hemisflo. Specific construction details for the parachutes are shown in Figs. 5 through 14.

2.2.2.1 Hyperflo Parachutes

(U) General details of the hyperflo parachutes are given in Table I. The hyperflo parachutes were constructed using three general design concepts. Configurations H-2 and H-3 as seen in Fig. 6 were designed in the shape of a truncated cone. Configurations H-1, H-4, H-5, and H-6 were constructed in the shape that the truncated cone design assumes when it is in a fully aerodynamically inflated condition. Details of the shaped hyperflo parachute are shown in Figs. 5, 7, and 8. Configurations H-7, H-8, and H-9 incorporated a combination of the two design concepts described above. The straight skirt was taken from the H-2-type parachute and the shaped roof was similar to the H-1-type. Details of these parachutes are shown in Figs. 9 and 10. Porosity, defined in this report as the ratio of the open area of a canopy surface to the total canopy surface area, ranged from 7.0 to 10.9 percent for the hyperflo parachutes. Various weaves of either metal, nylon, HT-1, or a combination of nylon and HT-1 material were employed to vary the porosity of the parachutes. Porosity was also varied by applying a Silastic® 131 coating to the roofs of three configurations.

2.2.2.2 Hemisflo Parachutes

(U) The hemisflo parachutes were constructed of 2-in.-wide nylon ribbons. Configurations R-1 through R-3 were 10-ft-diam hemisflo parachutes with 12-percent porosity and 240-in. shroud lines. Configuration R-1 was reefed at diameters of 2, 3, 4, and 5 ft. Configuration R-2, using mid-gore reefing, was reefed at diameters of 2 and 3 ft. Configuration R-3 with 28 horizontal ribbons was reefed to a diameter

of 3 ft. Details of configurations R-1, R-2, and R-3 are shown in Fig. 11. Configurations R-4, R-5, and R-6 were 6-ft-diam hemisflo parachutes with porosities of 21, 10, and 10 percent, respectively, and 144-in. shroud lines. Details of configurations R-4 and R-5 are shown in Fig. 12. Configuration R-6 had a solid HT-1 mesh skirt in addition to the nylon ribbon roof and is shown in Fig. 13. Configuration R-7 was a 5.5-ft-diam hemisflo parachute with 18-percent porosity and 132-in. shroud lines. Details of this configuration are shown in Fig. 14.

SECTION III
PROCEDURE

(U) Prior to tunnel operation, the parachute was packed into the aft end of the centerbody. After tunnel conditions were established, the parachute was deployed by a compressed spring. Motion pictures and dynamic drag data were obtained during and after each deployment. After the parachute deployment had been completed, the analog signal from the strain-gage load cell was averaged over one-second intervals to calculate a steady-state drag load. Tunnel conditions were then changed with the parachute still deployed. Motion pictures, steady-state drag, and dynamic drag data were obtained at all subsequent desired test conditions.

(U) All parachute configurations were investigated at Mach numbers in the range from 1.8 to 3.0. Dynamic pressure was maintained nominally at 120 psfa for all configurations which resulted in pressure altitudes from 82,000 to 104,000 ft over the Mach number range investigated. The model centerbody was maintained at zero angle of attack for the entire test.

SECTION IV
RESULTS AND DISCUSSION

(U) A limited amount of steady-state drag data was obtained during this test because of failures of the parachutes upon deployment or immediately following deployment. Other parachutes failed before they could be tested at more than one Mach number. As a result of disreefing immediately after deployment and unexpected high drag loads, four of the hemisflo configurations sheared a pin protecting the strain-gage load cell and departed from the centerbody before steady-state drag data could be obtained. Some of the parachute failures were caused by a deficiency

in the parachute material or construction. Some of the failures occurred because the parachutes were required to withstand constant loads at elevated Mach numbers for long durations of time; such failures were caused by material fatigue.

4.1 DEPLOYMENT LOADS

(U) As found in previous parachute testing (Ref. 1), the snatch load and opening shock load varied with each deployment. Snatch and opening-shock loads were found to vary between 100 and 5000 lb for all the deployments, although large snatch and opening-shock loads did not necessarily occur during the same deployment. It is believed that the snatch and opening-shock loads encountered are a function of the parachute packing procedures and the particular deployment system used for each parachute. Dynamic drag traces of two similar parachutes are shown in Fig. 15.

4.2 PARACHUTE STABILITY

(U) The behavior of a parachute moving through the air is governed by characteristics which, in airplane design, are called stability characteristics. Certain characteristic parameters have been established which, when known, allow the prediction of stability for specific airplanes or missiles. However, published data indicate only limited success in establishing similar parameters for parachutes. The parachute stability characteristics as discussed in this report are defined as the relative comparison of parachute oscillations based on the motion pictures acquired during the test. The reference parachute is an ideal model which has no oscillations or distorting moments to disturb the parachute from its equilibrium position.

4.3 HYPERFLO PARACHUTES

(U) The results of the tests conducted with the hyperflo parachutes are presented in Figs. 16 and 17 and Table II. In general, the drag coefficient and parachute drag parameter for the hyperflo parachutes were found to decrease with increasing Mach number. The drag coefficient for the fully inflated parachutes was found to range from 0.13 to 0.29. For the underinflated parachutes and the ones with torn roofs, the drag coefficient varied from approximately 0.05 to 0.08. The drag coefficients measured for each configuration are presented in Table II. Typical pictures taken during testing of a number of these parachutes are shown in Fig. 18.

(U) Stability and inflation characteristics of the hyperflo parachutes were visually studied from motion pictures. In general, the parachutes had good stability and inflation at Mach number 2.6. However, under-inflation and instability occurred as the Mach number was increased. Parachute roof failures limited testing of configurations H-1 and H-6 to Mach numbers of 2.2 and 2.6, respectively. These two configurations, however, had good stability and inflation at these Mach numbers. Configurations H-7 and H-9 with shaped roofs had poor stability at Mach number 2.6. Partially because of the instability, configurations H-7 and H-9 failed before they could be tested at more than one Mach number. Stability and inflation characteristics and the test conditions for each configuration tested are presented in Table II.

4.4 HEMISFLO PARACHUTES

(U) The results of the tests conducted on the hemisflo parachutes are presented in Figs. 19 and 20 and Table III. The drag coefficient for the hemisflo configurations was found to vary between 0.09 and 0.39. Configurations R-1 and R-2, reefed to a 2-ft diameter, show increases in drag coefficient with increasing Mach number. Motion pictures of these two parachutes indicated that several of the reefing rings failed as the Mach number was increased from 1.8 to 2.2. It is believed that the increase in parachute diameter caused by the partial disreefing caused the trend in increasing drag coefficient with increasing Mach number. The normal trend as shown in previous testing (Ref. 1) is a decrease in drag coefficient with an increase in Mach number.

(U) Attempts were made to test configuration R-1 at reefed diameters of 2, 3, 4, and 5 ft to determine the effect of different reef diameters in the 1.8 to 2.2 Mach number range. As a result of partial or total disreefing and unexpected high loads, the parachutes reefed to 3, 4, and 5 ft failed shortly after deployment and not enough steady-state drag data were obtained to show the effect of the reefed diameter.

(U) Configuration R-2, identical to R-1 in construction details, used a mid-gore reefing technique to reef the parachute diameter to 2 and 3 ft. At Mach number 1.8 and a reefed diameter of 2 ft, configuration R-2 with mid-gore reefing had a drag coefficient approximately 29-percent higher than configuration R-1 with conventional reefing. Because of the combination of partial disreefing and instability, configuration R-2, reefed to 3 ft, failed before steady-state drag data were obtained.

(U) Configuration R-3, reefed to a diameter of 3 ft, failed before data could be obtained at more than one Mach number.

(U) Configurations R-4, R-5, and R-6 were tested to determine the characteristics of a hemisflo parachute in the 2.6 to 3.0 Mach number range. Configurations R-4 and R-5 with porosities of 21 and 10 percent, respectively, were tested at Mach number 2.6 and failed before reaching a higher Mach number. Motion pictures showed that these two parachutes had fair stability and inflation characteristics at Mach number 2.6. The design concept of configuration R-6 was a combination of a hyperflo skirt and a hemisflo roof. No steady-state drag data were obtained for configuration R-6 as the tunnel flow broke one second after deployment. However, good inflation and fair stability were observed in the motion pictures acquired of this parachute.

(U) Configuration R-7, a 5.5-ft-diam unreefed parachute, was tested through the 1.8 to 2.2 Mach number range. The drag coefficient and drag parameter of this parachute decreased with increasing Mach number.

(U) All the hemisflo parachutes investigated had fair to good stability and inflation characteristics. The motion pictures indicated that there was no appreciable effect of Mach number on the stability or inflation of any given configuration. Figure 21 shows typical pictures taken during testing that illustrate the inflation characteristics of the hemisflo parachutes.

SECTION V
CONCLUDING REMARKS

(U) Tests were conducted to investigate the drag, stability, and inflation characteristics of several hyperflo and hemisflo parachute configurations in the Mach number range from 1.8 to 3.0. The following observations are a result of these tests:

1. In general the drag coefficient and drag parameter for the hyperflo parachutes decreased with increasing Mach number.
2. The hyperflo parachutes had good inflation at Mach number 2.6.
3. The hemisflo parachutes had good inflation in the 1.8 to 2.2 Mach number range.
4. At Mach number 2.6, the hemisflo parachute using the mid-gore reefing technique had a higher drag coefficient than the hemisflo parachute using conventional reefing.

5. For a given configuration, the stability was essentially unchanged with varying Mach number.

REFERENCES

1. Lowry, J. F. (U) "Aerodynamic Characteristics of Various Types of Full-Scale Parachutes at Mach Numbers from 1.8 to 3.0." AEDC-TDR-64-120 (AD351001) June 1964. [redacted]

2. Test Facilities Handbook, (5th Edition). "Propulsion Wind Tunnel Facility, Vol. 3." Arnold Engineering Development Center, July 1963. (UNCLASSIFIED)

UNCLASSIFIED

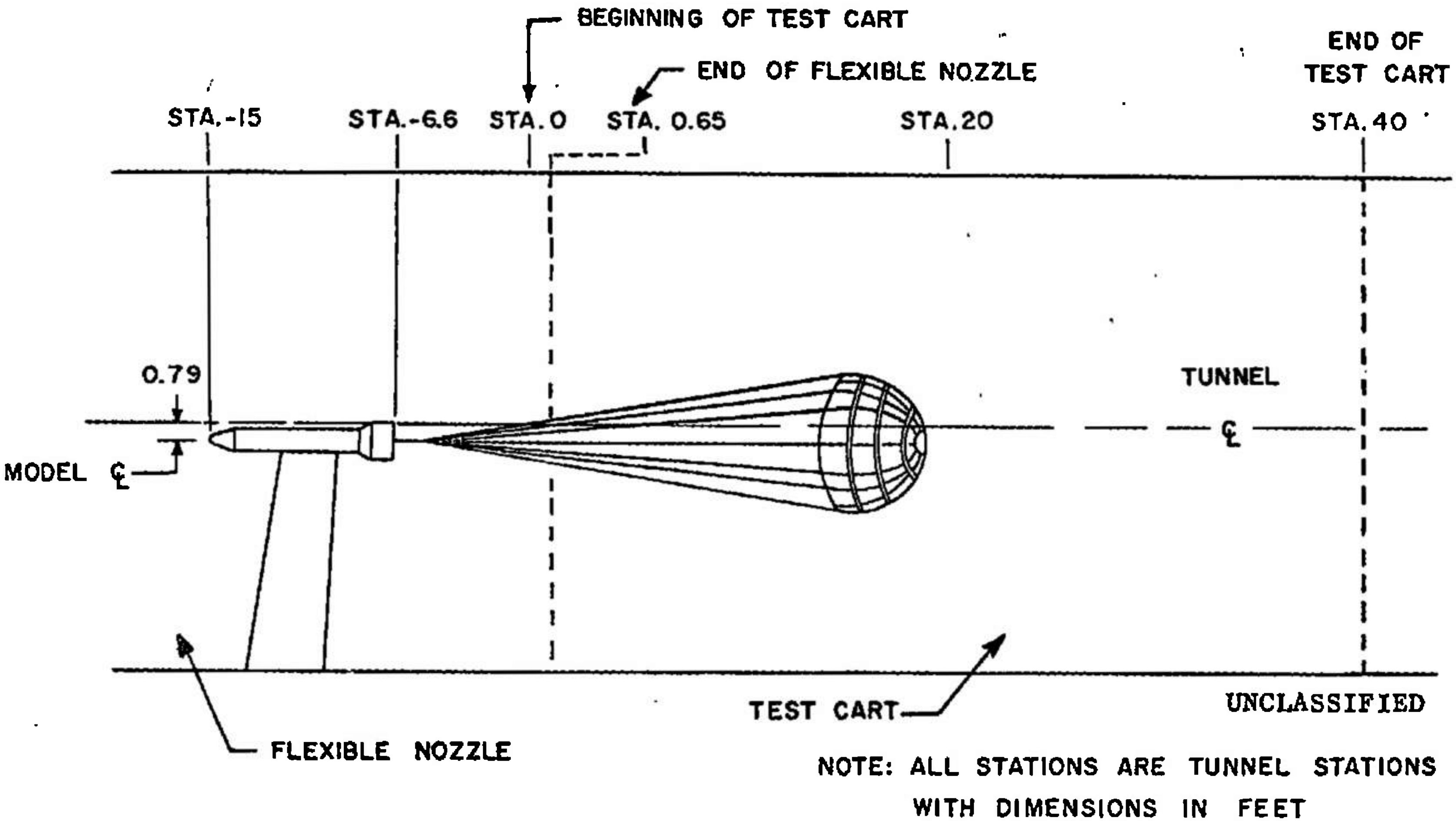


Fig. 1 Location of Model Centerbody in 16S Test Section

UNCLASSIFIED

UNCLASSIFIED

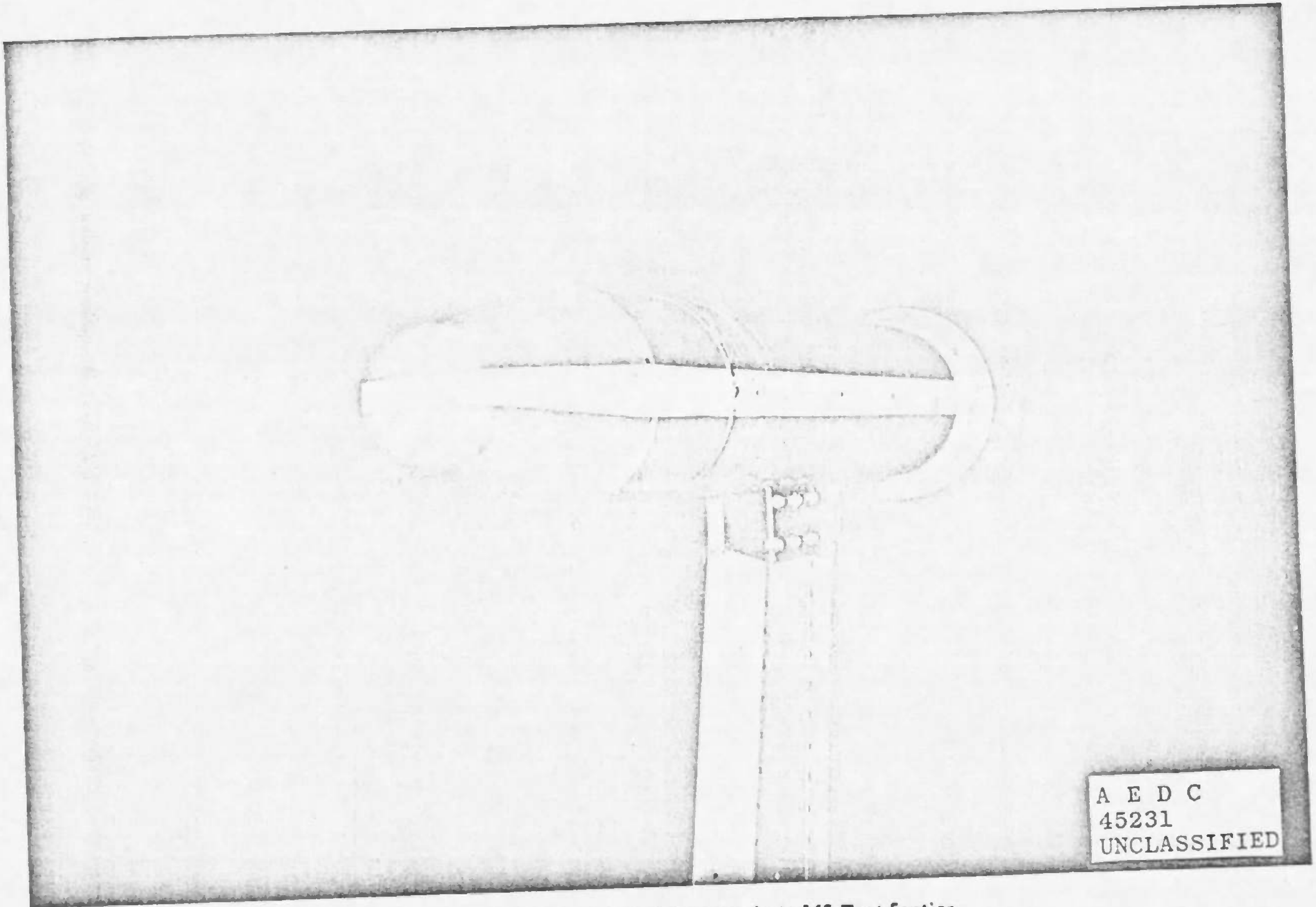


Fig. 2 Installation of Model Centerbody in 16S Test Section

UNCLASSIFIED

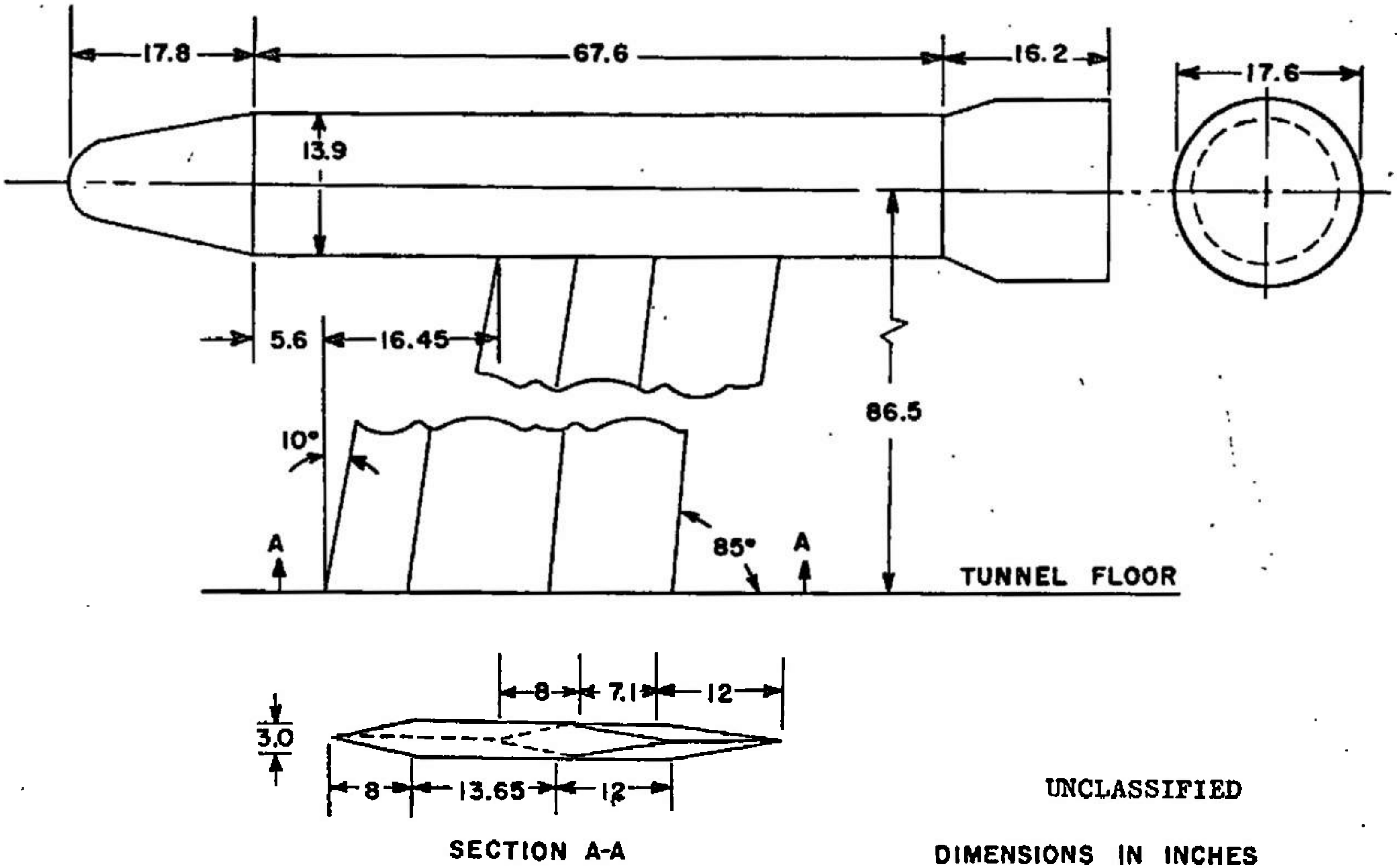


Fig. 3 Model Centerbody Dimensions

UNCLASSIFIED

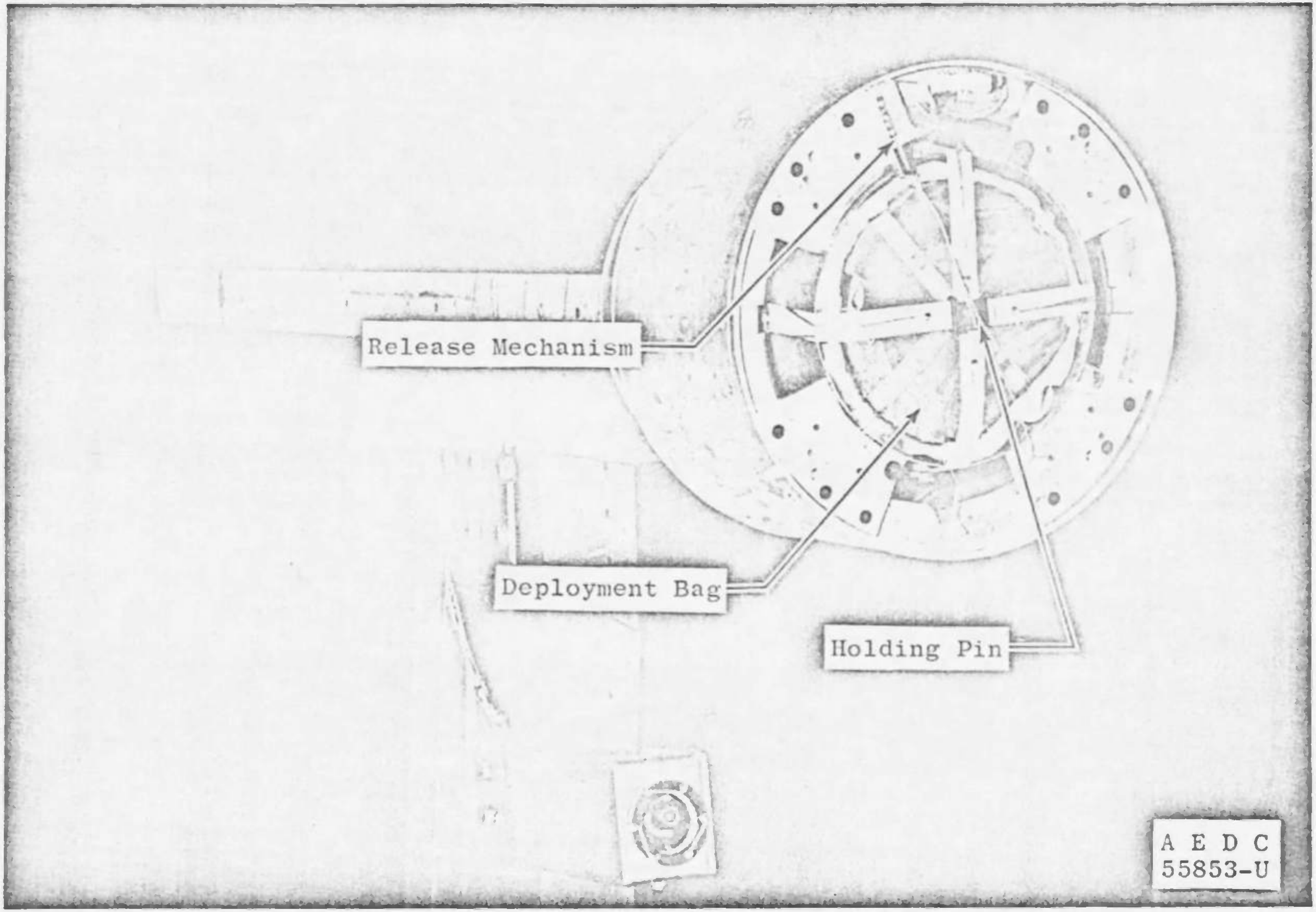
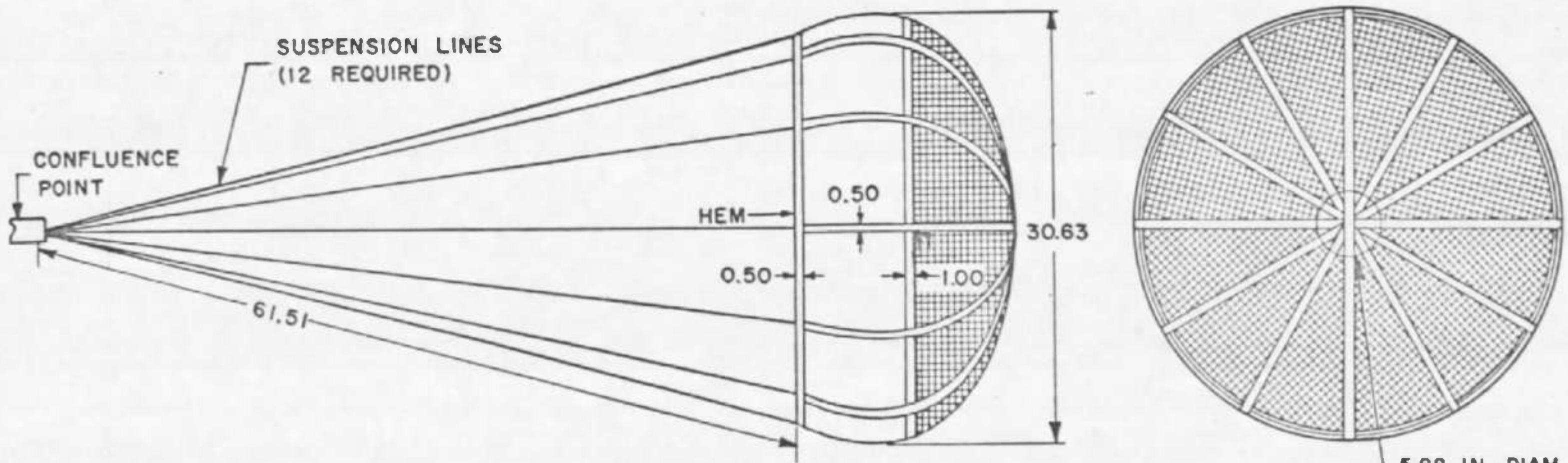
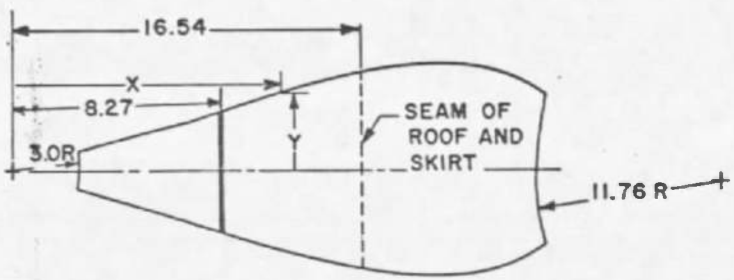


Fig. 4 Installation of Parachute in Model Centerbody

[redacted]





ROOF AND SKIRT GORE

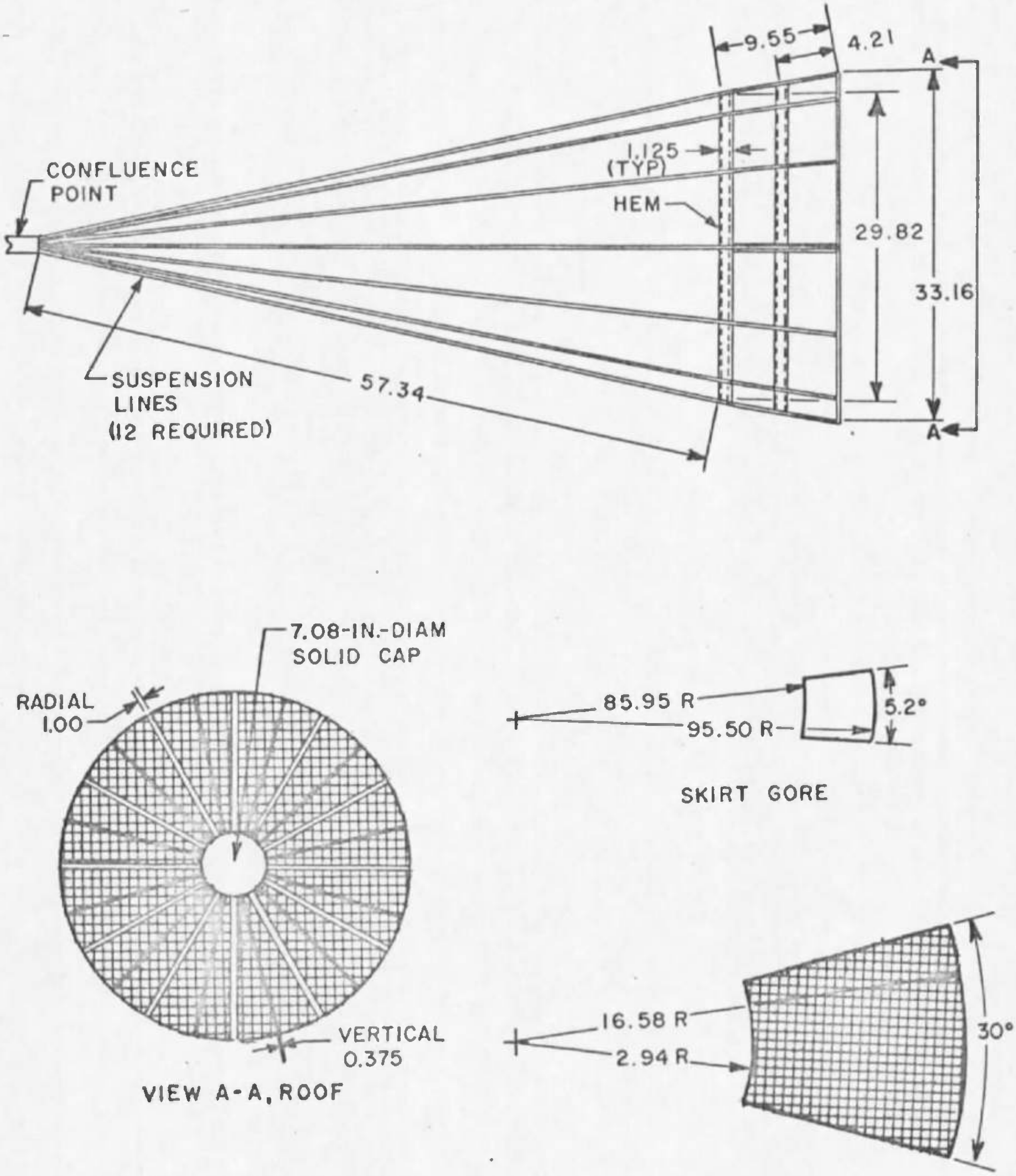
ROOF AND SKIRT GORE COORDINATES

X	Y	X	Y
0.766	0.199	15.315	4.365
1.532	0.429	16.540	4.595
3.063	0.843	16.847	4.641
4.595	1.271	18.378	4.840
6.126	1.700	19.910	4.901
7.658	2.144	20.032	4.916
9.189	2.603	21.441	4.824
10.721	3.063	22.973	4.472
12.252	3.523	24.504	3.875
13.784	3.951	25.117	3.569

NOTE: ALL DIMENSIONS IN INCHES

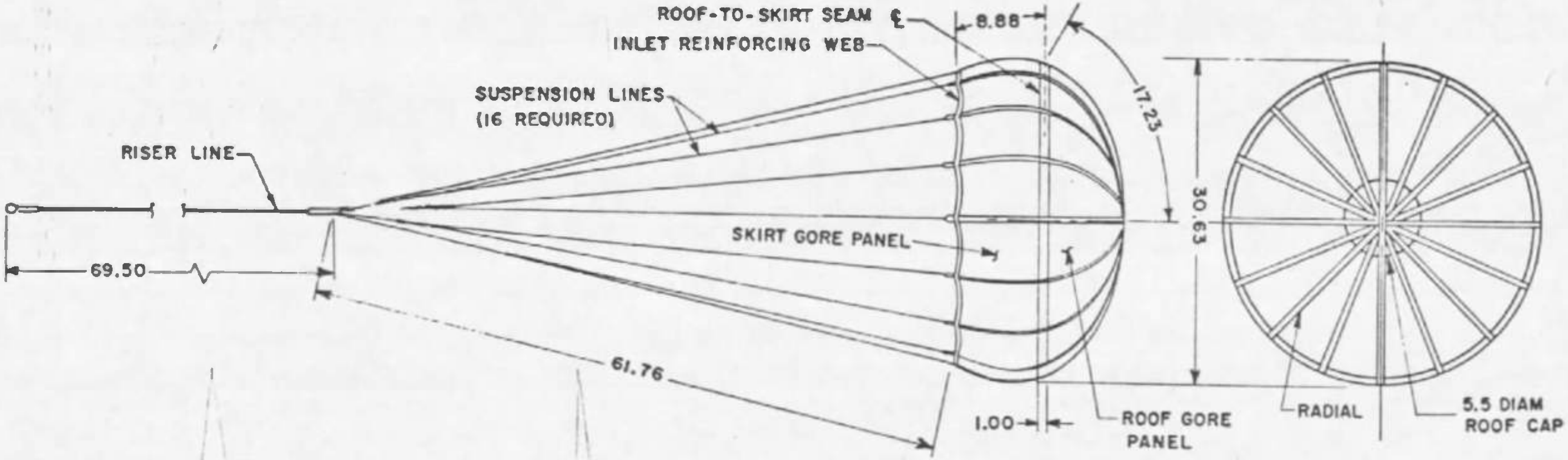
[redacted]

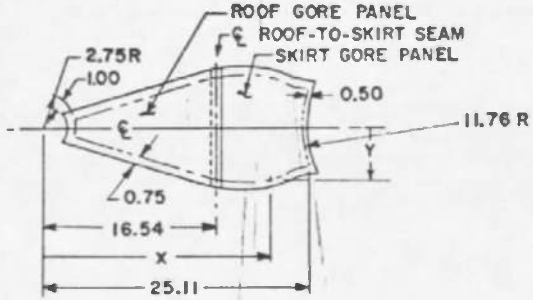
Fig. 5 Hyperflo Parachute Details, Configuration H-1



NOTE: ALL DIMENSIONS IN INCHES

Fig. 6 Hyperflo Parachute Details, Configurations H-2 and H-3





CANOPY GORE PATTERN

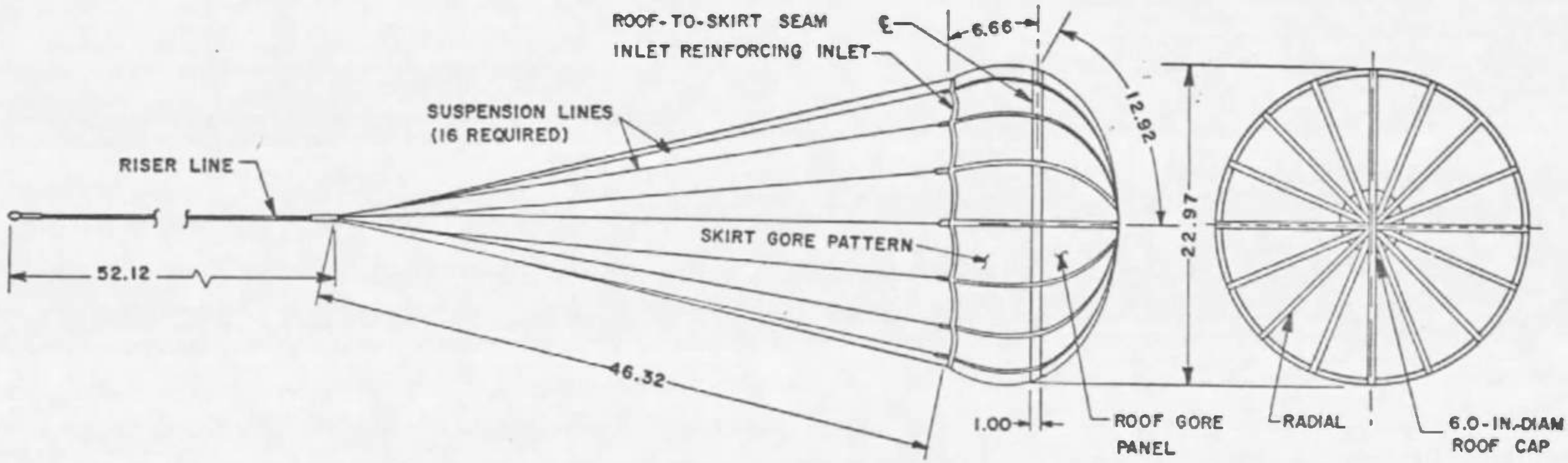
GORE COORDINATES

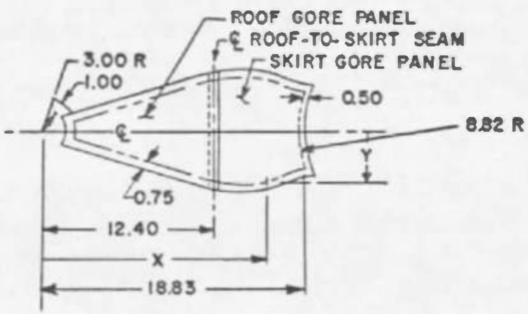
X	Y
0	0
3.06	0.84
6.12	1.70
9.19	2.60
12.25	3.52
15.32	4.36
16.54	4.59
18.38	4.84
20.03	4.91
21.44	4.78
22.16	4.56
22.94	4.24
23.46	3.97
24.00	3.71
24.53	3.58
25.11	3.57

[redacted]

NOTE: ALL DIMENSIONS IN INCHES

Fig. 7 Hyperflo Parachute Details, Configurations H-4 and H-5



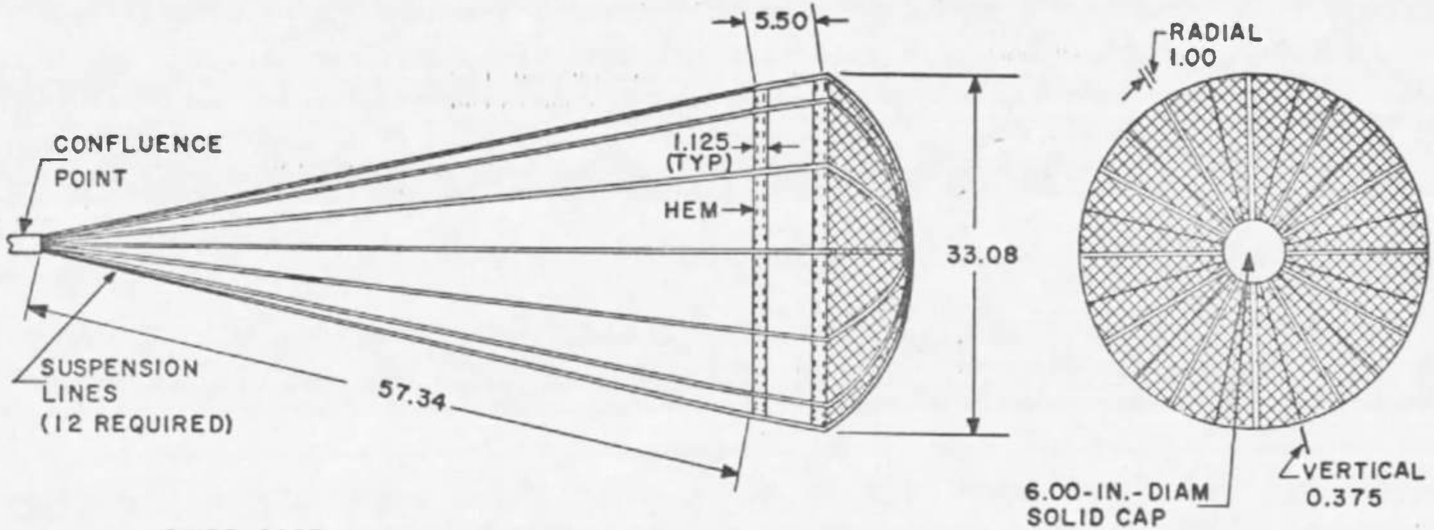


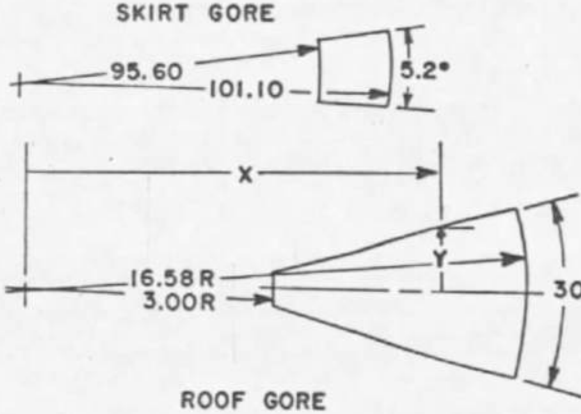
GORE COORDINATES

X	Y
0	0
2.29	0.63
4.59	1.27
6.89	1.95
9.19	2.64
11.49	3.27
12.40	3.44
13.78	3.63
15.02	3.68
16.08	3.58
16.62	3.42
17.20	3.18
17.59	2.98
18.00	2.78
18.40	2.68
18.83	2.67

NOTE: ALL DIMENSIONS IN INCHES

Fig. 8 Hyperflo Parachute Details, Configuration H-6





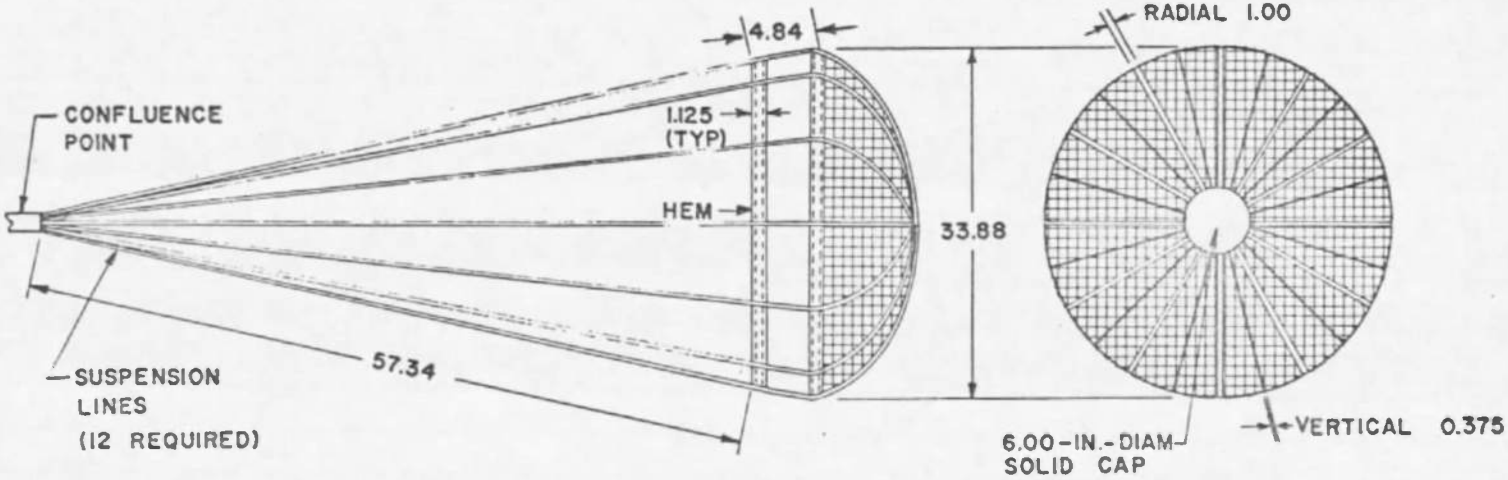
NOTE: ALL DIMENSIONS IN INCHES

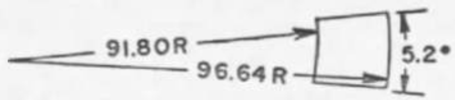
ROOF COORDINATES

X	Y
0	0
0.766	0.199
1.532	0.429
3.063	0.843
4.595	1.271
6.126	1.700
7.658	2.144
9.189	2.603
10.721	3.063
12.252	3.523
13.784	3.951
15.315	4.365
16.540	4.595

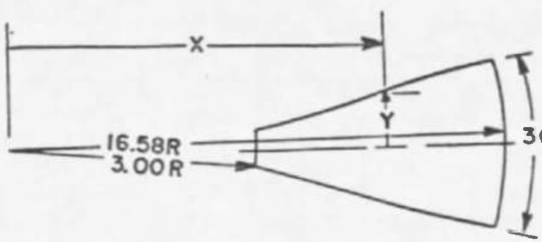
Fig. 9 Hyperflo Parachute Details, Configurations H-7 and H-8

[redacted]





SKIRT GORE



ROOF GORE

ROOF COORDINATES

X	Y
0	0
3.00	0.73
6.00	1.50
9.00	2.27
12.00	3.11
15.00	3.90
16.50	4.25
17.25	4.40

NOTE: ALL DIMENSIONS IN INCHES

[redacted]

Fig. 10 Hyperflo Parachute Details, Configuration H-9

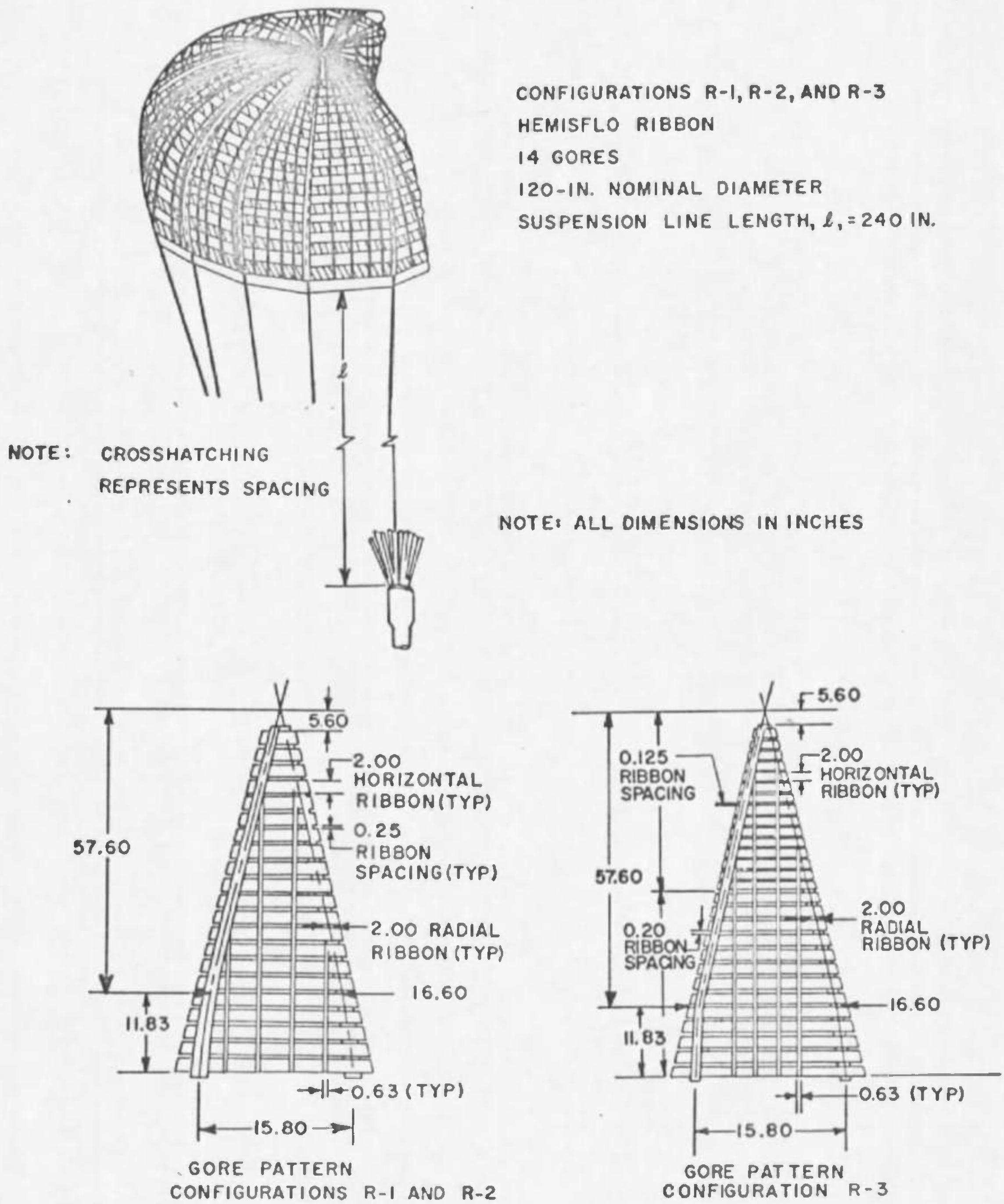
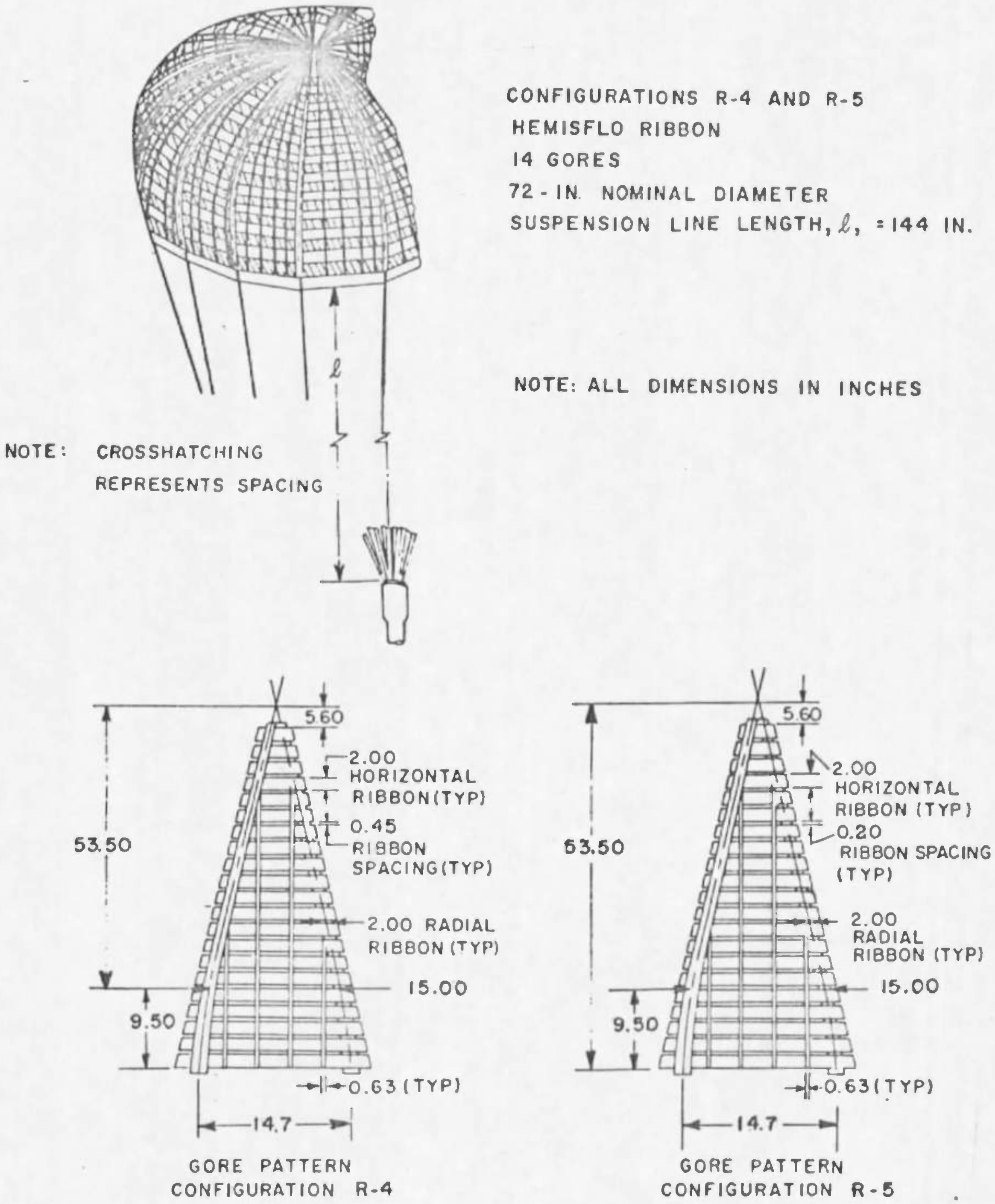
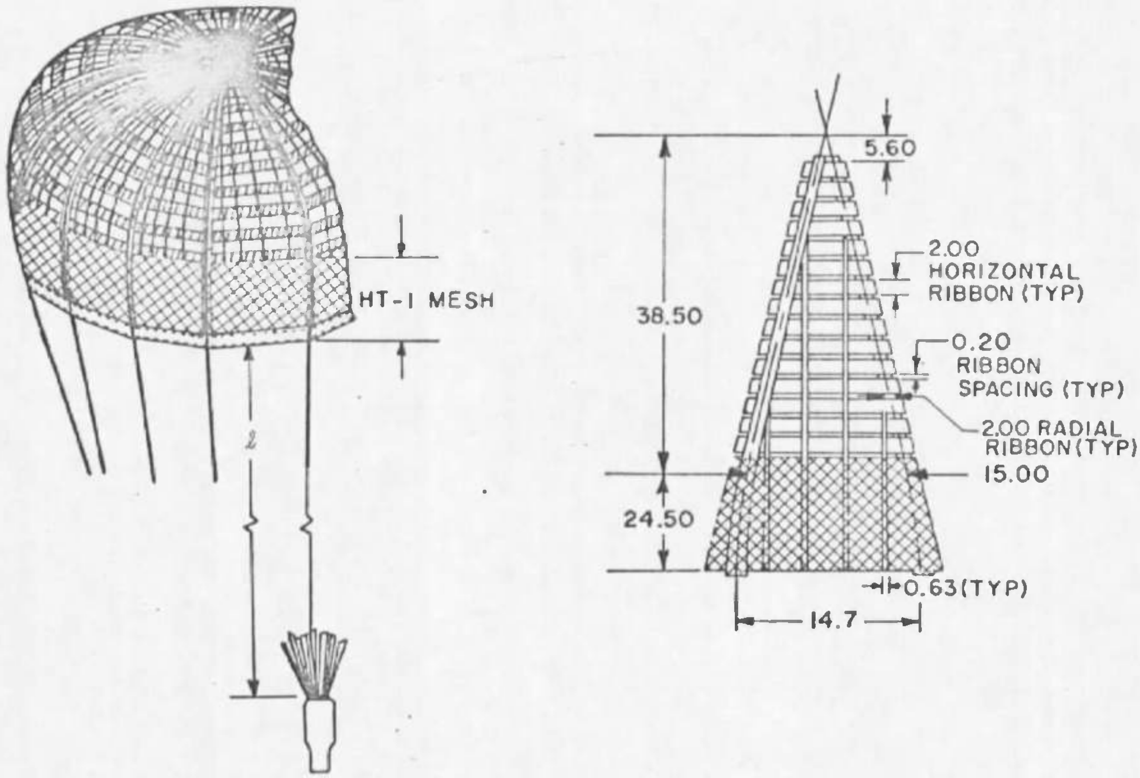


Fig. 11 Hemisflo Parachute Details, Configurations R-1, R-2, and R-3



UNCLASSIFIED

Fig. 12 Hemisflo Parachute Details, Configurations R-4 and R-5

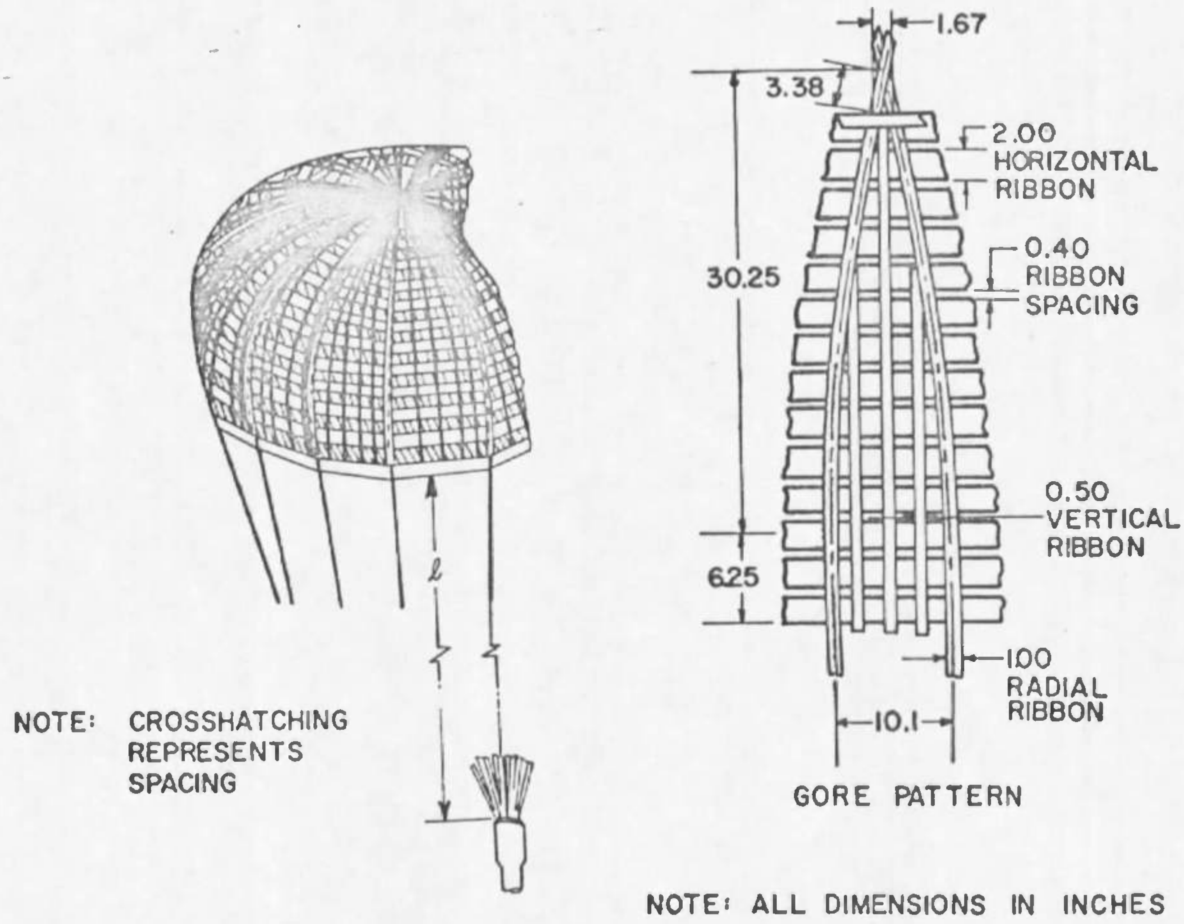


NOTE: ALL DIMENSIONS IN INCHES

CONFIGURATION R-6
HEMISFLO RIBBON
14 GORES
72 - IN. NOMINAL DIAMETER
SUSPENSION LINE LENGTH, ℓ, = 144 IN.

UNCLASSIFIED

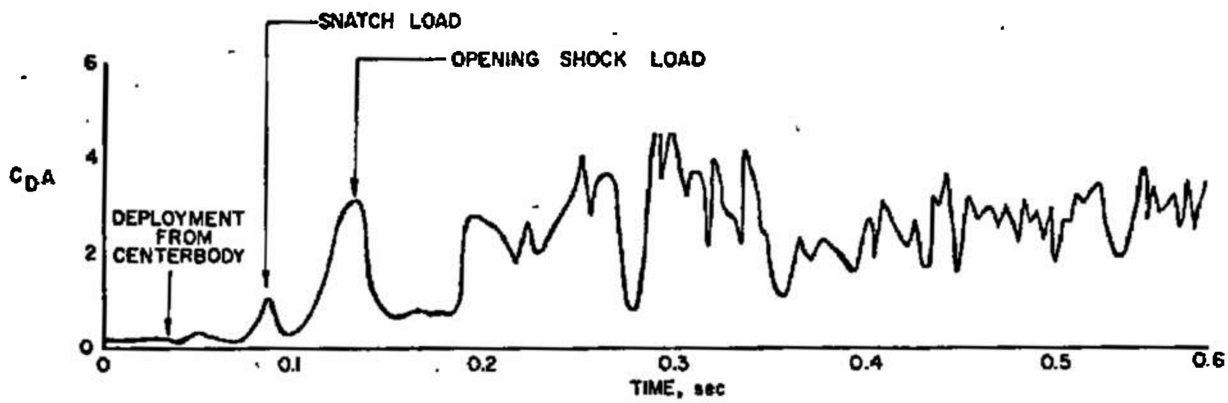
Fig. 13 Hemisflo Parachute Details, Configuration R-6

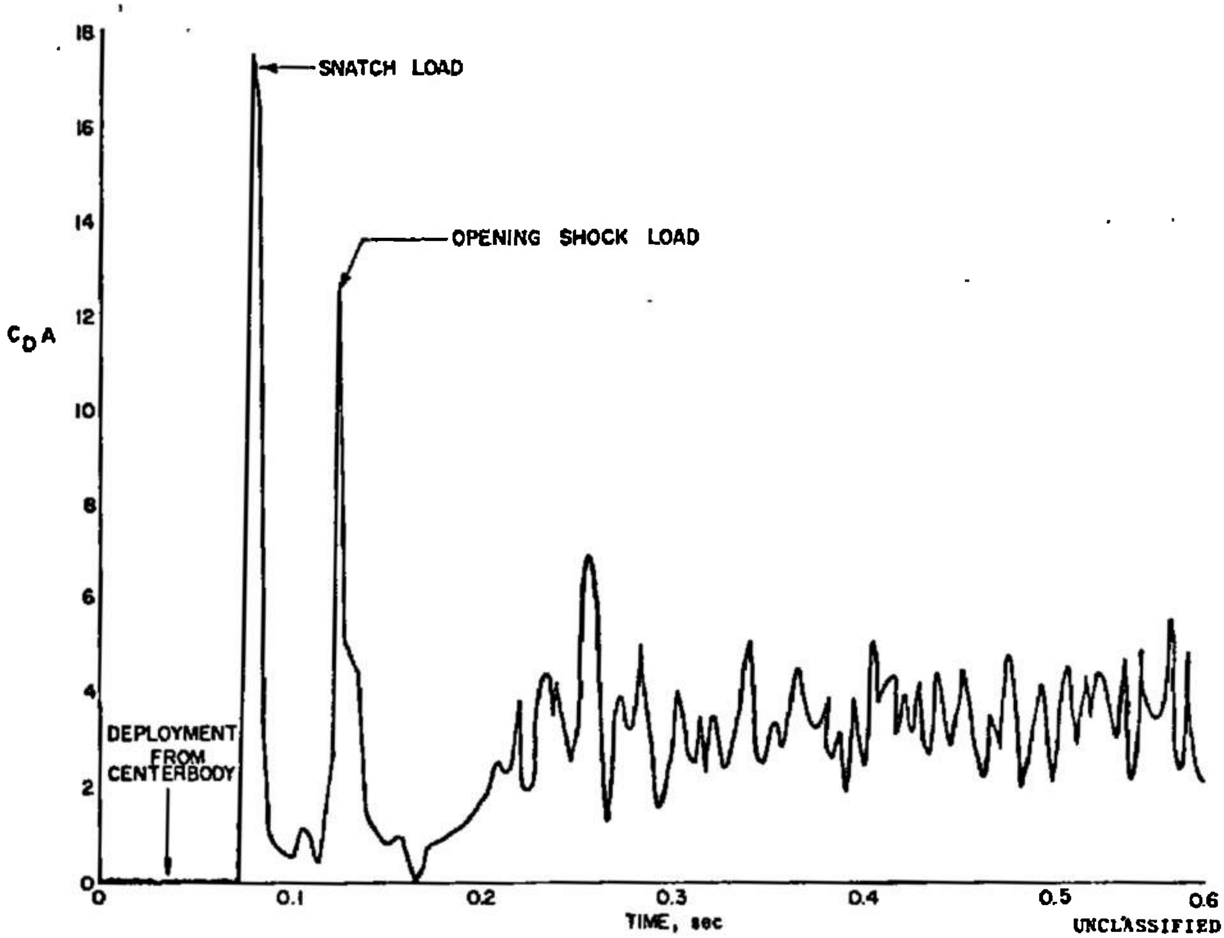


CONFIGURATION R-7
HEMISFLO RIBBON
12 GORES
66-IN. NOMINAL DIAMETER
SUSPENSION LINE LENGTH, ℓ, =132-IN.

UNCLASSIFIED

Fig. 14 Hemisflo Parachute Details, Configuration R-7





UNCLASSIFIED

Fig. 15 Deployment Characteristics of Two Similar Parachutes

UNCLASSIFIED

CONFIGURATION	PERCENT POROSITY	CONFIGURATION	PERCENT POROSITY
H-1	8.7	H-6	10.9
H-2	9.0	H-7	9.6
H-3	9.0	H-8	9.6
H-4	9.6	H-9	9.6
H-5	7.0		

NOTE: SOLID SYMBOLS - POOR INFLATION

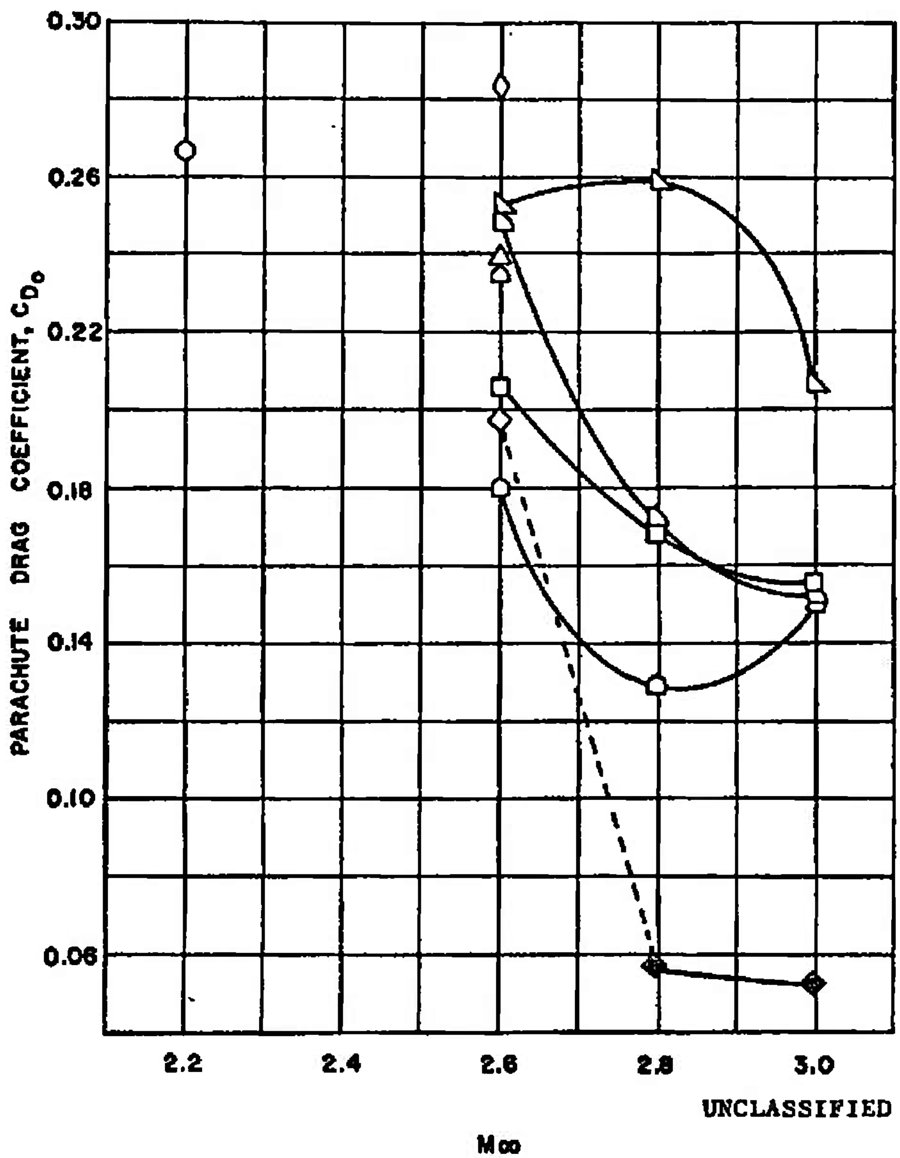


Fig. 16 Variation of Drag Coefficient with Mach Number for Hyperflo Parachute Configurations

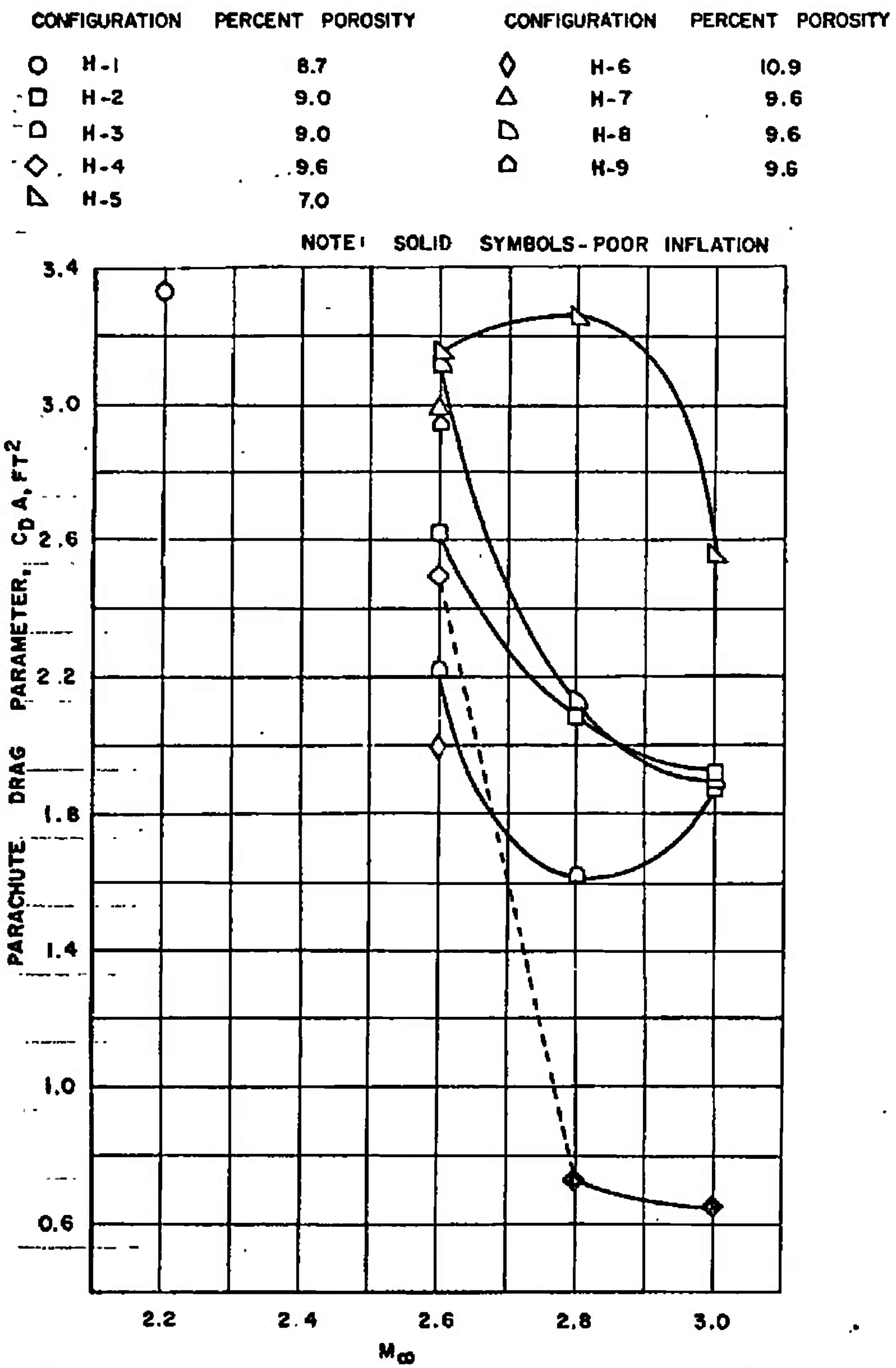
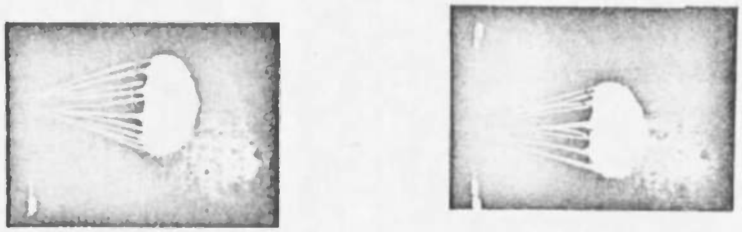


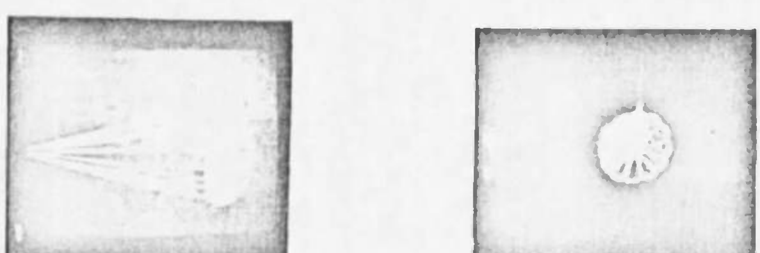
Fig. 17 Variation of the Parachute Drag Parameter with Mach Number for Hyperflo Parachute Configurations



a. Configuration H-3, 9.0-percent Porosity, $M_{\infty} = 2.6$

b. Configuration H-4, 9.6-percent Porosity, $M_{\infty} = 2.6$

c. Configuration H-5, 7.0-percent Porosity, $M_{\infty} = 2.6$



d. Configuration H-8, 9.6-percent Porosity, $M_{\infty} = 2.6$

UNCLASSIFIED

Fig. 18 Photographs of Hyperflo Parachutes during Tests

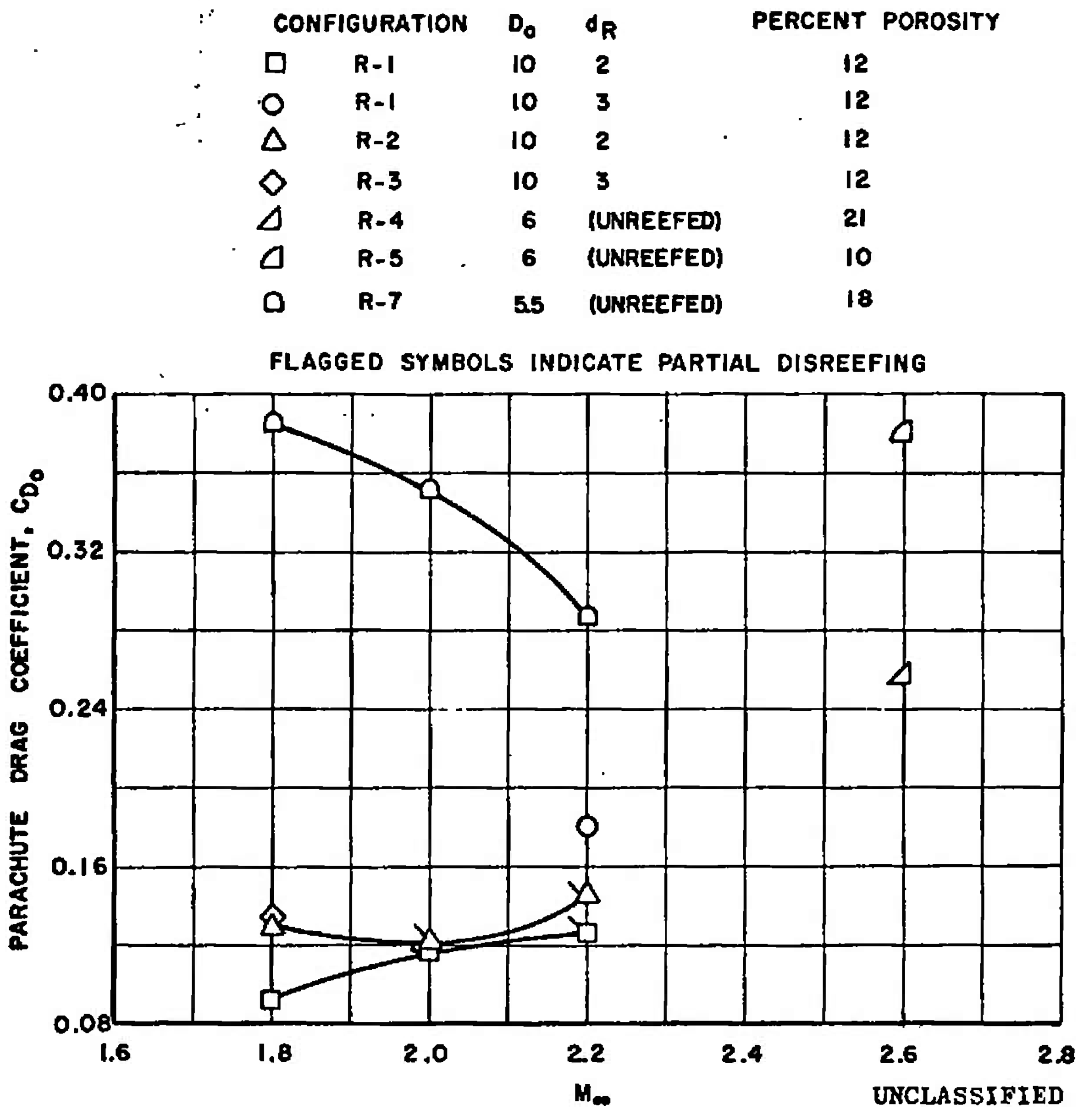
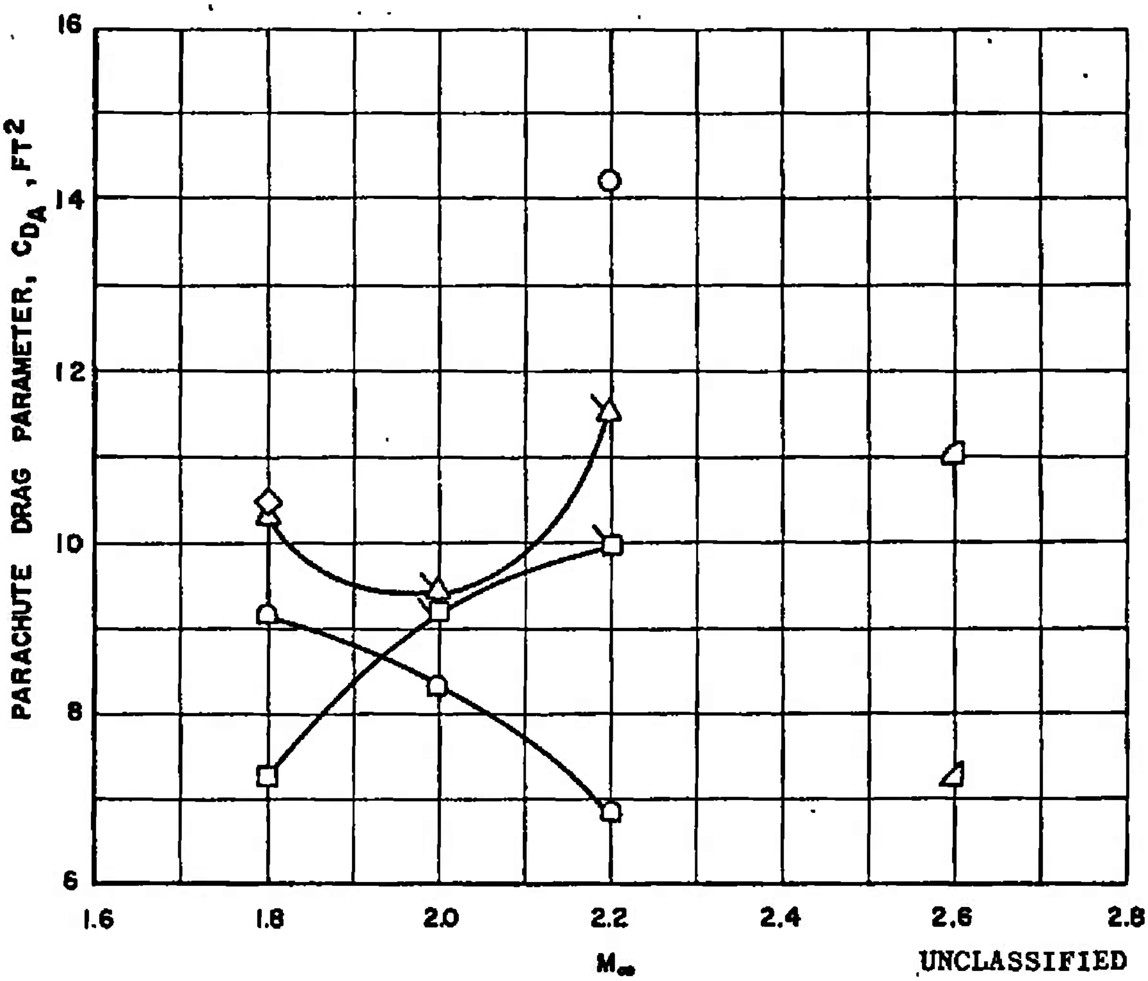


Fig. 19 Variation of Drag Coefficient with Mach Number for Hemisflo Parachute Configurations

UNCLASSIFIED

	CONFIGURATION	D_o	d_R	PERCENT POROSITY
□	R-1	10	2	12
○	R-1	10	3	12
△	R-2	10	2	12
◇	R-3	10	3	12
◺	R-4	6	(UNREEFED)	21
◻	R-5	6	(UNREEFED)	10
⌂	R-7	5.5	(UNREEFED)	18

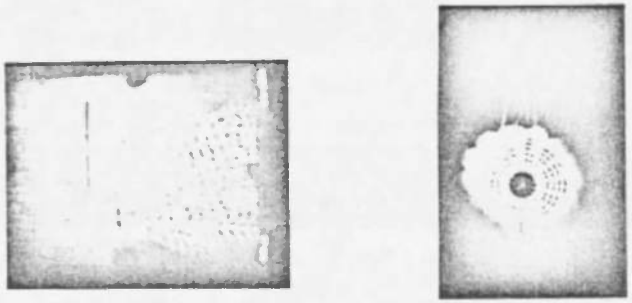
FLAGGED SYMBOLS INDICATE PARTIAL DISREEFING



UNCLASSIFIED

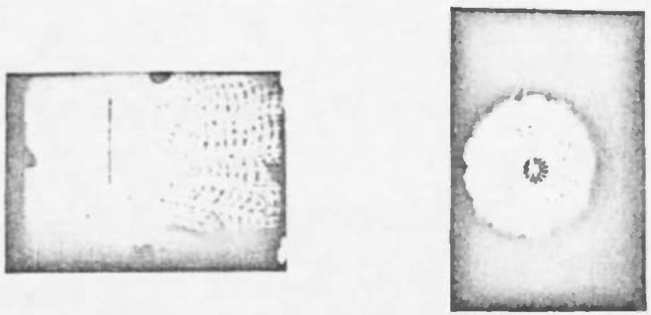
Fig. 20 Variation of the Parachute Drag Parameter with Mach Number for Hemisflo Parachute Configurations

UNCLASSIFIED

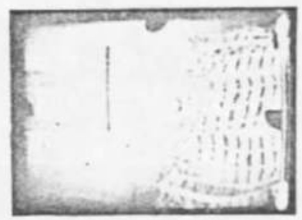


a. Configuration R-1, 12-percent Porosity, $M_\infty = 1.80$, $d_R = 2.0$ ft

b. Configuration R-5, 10-percent Porosity, $M_\infty = 2.60$



c. Configuration R-3, 12-percent Porosity, $M_\infty = 1.80$, $d_R = 2.0$ ft



d. Configuration R-3, 12-percent Porosity, $M_\infty = 2.20$, $d_R = 3.0$ ft

Fig. 21 Photographs of Hemisflo Parachutes during Tests

TABLE 1
PARACHUTE MATERIAL DETAILS

Configuration	Type	Porosity, percent	Description
H-1	Hyperflo	8.7	HT-1 mesh roof material having a 24-percent porosity with an 11-in.-radius circle from center of parachute coated with silicone to give a porosity of 10.9 for the circle. HT-1 skirt material.
H-2	Hyperflo	9.00	HT-1 mesh roof material with a thread count of 18/in. (3 strands per thread) by 20/in. (3 strands per thread) and nylon skirt material. This parachute has 4500-lb nylon webbing reinforcement at both top and bottom of skirt.
H-3	Hyperflo	9.00	HT-1 mesh roof material with a thread count of 18/in. (3 strands per thread) by 20/in. and nylon skirt material. This parachute has 1000-lb nylon webbing reinforcement at both top and bottom of skirt.
H-4	Hyperflo	9.60	HT-1 mesh roof material with a thread count of 18/in. (3 strands per thread) by 20/in. (3 strands per thread) and nylon skirt material.
H-5	Hyperflo	7.00	HT-1 mesh roof material having a 28.4-percent porosity with an 11-in.-radius circle from center of parachute coated with silicone to give a porosity of 11.2 percent and a 21.3-percent porosity for a ring from 11-in. radius to 13-in. radius. Excess cloth in the skirt was taken out with pleats.

TABLE I (Continued)

Configuration	Type	Porosity, percent	Description
H-6	Hyperflo	10.9	This parachute was a 3/4-scale of configuration H-5 constructed of metal cloth. The basic metal cloth was 27-percent porous with a silicone coating used to control porosity. The skirt as well as the 6-in. cap was coated to reduce the porosity to zero.
H-7	Hyperflo	9.60	HT-1 mesh roof material with a thread count of 18/in. (3 strands per thread) by 20/in. (3 strands per thread) and nylon skirt material.
H-8	Hyperflo	9.60	Nylon native lace mesh material and nylon skirt material.
H-9	Hyperflo	9.60	HT-1 mesh roof material with a thread count of 18/in. (3 strands per thread) by 20/in. (3 strands per thread) and nylon skirt material.
R-1	Hemisflo	12.0	10-ft-diam parachute constructed of 21 horizontal 2-in.-wide nylon ribbons with 240-in. nylon suspension lines.
R-2	Hemisflo	12.0	10-ft-diam parachute constructed of 21 horizontal 2-in.-wide nylon ribbons with 240-in. nylon suspension lines. This parachute was reefed to smaller diameter by using a mid-gore reefing technique.
R-3	Hemisflo	12.0	10-ft-diam parachute constructed of 28 horizontal 2-in.-wide nylon ribbons with 240-in. nylon suspension lines.

TABLE I (Concluded)

Configuration	Type	Porosity, percent	Description
R-4	Hemisflo	21.0	6-ft-diam parachute constructed of 2-in.-wide nylon ribbon with 144-in. nylon suspension lines.
R-5	Hemisflo	10.0	6-ft-diam parachute constructed of 2-in.-wide nylon ribbon with 144-in. nylon suspension lines.
R-6	Hemisflo	10.0	6-ft-diam parachute constructed of 2-in.-wide nylon ribbon with 144-in. nylon suspension lines. This parachute has a solid HT-1 mesh skirt.
R-7	Hemisflo	18.0	5.5-ft-diam parachute constructed of 2-in.-wide nylon ribbon with 132-in. nylon suspension lines.

TABLE II
HYPERFLO PARACHUTE TEST CONDITIONS AND RESULTS

Config.	M_∞	q_∞	X/D	S_o	C_{D_o}	Observations
H-1	2.20	120.0	9.75	12.57	0.266	Good stability, good inflation, slight rotation, roof failed.
H-2	2.60	120.0	9.75	12.57	0.206	Fair stability, good inflation.
	2.80	120.8	9.75	12.57	0.167	Fair stability, fair inflation with intermittent squidding.
	3.00	120.5	9.75	12.57	0.152	Fair stability, fair inflation with intermittent squidding.
H-3	2.60	120.3	9.75	12.57	0.179	Good stability, good inflation, light squidding.
	2.80	120.4	9.75	12.57	0.126	Fair stability, fair inflation with intermittent heavy squidding.
	3.00	120.5	9.75	12.57	0.149	Fair stability, fair inflation with intermittent heavy squidding.
H-4	2.60	119.3	9.75	12.57	0.198	Good stability, good inflation, light squidding.
	2.80	119.7	9.75	12.57	0.056	Fair stability, poor inflation, assumed a full reefed condition.
	3.00	120.7	9.75	12.57	0.052	Fair stability, poor inflation, assumed a full reefed condition.
H-5	2.60	120.1	9.75	12.57	0.252	Good stability, good inflation.
	2.80	120.3	9.75	12.57	0.259	Good stability, good inflation.
	3.00	120.6	9.75	12.57	0.204	Poor stability, good inflation, roof failing.

TABLE II (Concluded)

Config.	M_∞	q_∞	X/D	S_o	C_{D_o}	Observations
H-6	2.60	120.2	5.80	7.07	0.283	Good stability, good inflation, roof failed.
H-7	2.60	120.8	9.75	12.57	0.239	Poor stability, good inflation, suspension line failed.
H-8	{ 2.60	120.1	9.75	12.57	0.248	Good stability, good inflation.
	2.80	120.0	9.75	12.57	0.170	Fair stability, fair inflation, two suspension lines failed.
	3.00	120.0	9.75	12.57	0.150	Fair stability, fair inflation, four suspension lines failed.
H-9	2.60	120.0	9.75	12.57	0.233	Poor stability, fair inflation, suspension line failed.

{ Denotes continuous run

TABLE III
HEMISFLO PARACHUTE TEST CONDITIONS AND RESULTS

Config.	M_∞	q_∞	X/D	S_o	d_R	C_{D_o}	Observations
R-1	2.20	119.0	14.5	78.54	5.0	-	No steady-state data were obtained. Disreefed and departed on deployment.
R-1	1.80	121.1	14.5	78.54	4.0	-	No steady-state data were obtained. Fair stability, fair inflation with light squidding. Departed 3 seconds after deployment.
R-1	2.20	120.8	14.5	78.54	3.0	0.181	Good stability, good inflation, partially disreefed. Departed 5 seconds after deployment.
R-1	1.80	120.0	14.5	78.54	2.0	0.092	Very good stability, very good inflation.
	2.00	120.5	14.5	78.54	2.0	0.116	Very good stability, very good inflation, partially disreefed.
	2.20	120.0	14.5	78.54	2.0	0.126	Good stability, good inflation, partially disreefed.
R-2	2.20	120.5	14.5	78.54	3.0	-	No steady-state data were obtained. Poor stability, good inflation, partially disreefed and departed.
R-2	1.80	12.16	14.5	78.54	2.0	0.131	Good stability, good inflation.
	2.00	120.7	14.5	78.54	2.0	0.120	Good stability, good inflation, partially disreefed.
	2.20	120.0	14.5	78.54	2.0	0.148	Good stability, good inflation, partially disreefed.
R-3	1.80	120.0	14.5	78.54	3.0	0.132	Fair stability, fair inflation with rapid breathing. Disreefed and departed.

TABLE III (Concluded)

Config.	M_∞	q_∞	X/D	S_o	d_R	C_{D_o}	Observations
R-4	2.60	120.4	9.2	28.27	-	0.250	Fair stability, fair inflation with light squidding. Suspension line failed.
R-5	2.60	120.6	9.2	28.27	-	0.389	Fair to poor stability, fair inflation with intermittent heavy squidding. Suspension line failed.
R-6	2.60	120.1	9.2	28.27	-	-	No steady-state data were obtained. Broke tunnel flow one second after deployment. Fair stability, good inflation.
R-7	1.80	120.2	12.8	23.76	-	0.383	Fair stability, good inflation.
	2.00	120.5	12.8	23.76	-	0.349	Fair to poor stability, good inflation.
	2.20	120.2	12.8	23.76	-	0.285	Fair to poor stability, good inflation.

{ Denotes continuous run

UNCLASSIFIED DECLASSIFIED
Security Classification

UNCLASSIFIED

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Arnold Engineering Development Center
ARO, Inc., Operating Contractor
Arnold Air Force Station, Tennessee

2a. REPORT SECURITY CLASSIFICATION
[redacted]
Unclassified

2b. GROUP
X

3. REPORT TITLE
AERODYNAMIC PERFORMANCE OF VARIOUS HYPERFLO AND HEMISFLO PARACHUTES AT MACH NUMBERS FROM 1.8 TO 3.0

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
N/A

5. AUTHOR(S) (Last name, first name, initial)
Reichenau, David E. A., ARO, Inc.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
March 1965	46	2

8a. CONTRACT OR GRANT NO.
AF 40(600)-1000
b. PROJECT NO. 6065
c. Program Element 62405364
d.

9a. ORIGINATOR'S REPORT NUMBER(S)
AEDC-TR-65-57

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
N/A

10. AVAILABILITY/LIMITATION NOTICES
~~Qualified requesters may obtain copies of this report from DDC.~~

11. SUPPLEMENTARY NOTES
N/A

12. SPONSORING MILITARY ACTIVITY
Research and Technology Division
Air Force Systems Command
Wright-Patterson AFB, Ohio

13. ABSTRACT

As an extension of studies previously completed, a test was conducted in the Propulsion Wind Tunnel, Supersonic (16S), to determine the effect of Mach number on the drag, stability, and inflation characteristics of a number of parachutes. The parachute characteristics were investigated at Mach numbers from 1.8 to 3.0 at pressure altitudes from 82,000 to 104,000 ft. Two general types of parachutes were tested: the hyperflo-type parachute using three general design concepts with porosities from 7.0 to 10.9 percent and the hemisflo-type parachute with and without reefing. Data obtained indicated that the hyperflo parachutes had good inflation characteristics at Mach number 2.6 and the drag decreased with increasing Mach number. The hemisflo parachutes had good inflation characteristics in the 1.8 to 2.2 Mach number range. For any given configuration, the stability was found to be essentially constant with varying Mach number. (U)

DD FORM 1 JAN 64 1473

DECLASSIFIED UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Parachutes Hyperflo Hemisflo Supersonic Flow Drag Stability Inflation						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
______________________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
______________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
______________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.